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# DS1337

## I<sup>2</sup>C Serial Real-Time Clock

### GENERAL DESCRIPTION

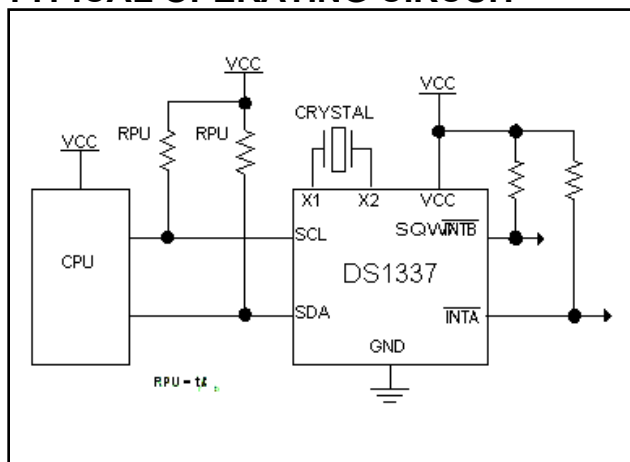
The DS1337 serial real-time clock is a low-power clock/calendar with two programmable time-of-day alarms and a programmable square-wave output. Address and data are transferred serially through an I<sup>2</sup>C bus. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with AM/PM indicator.

The device is fully accessible through the serial interface while V<sub>CC</sub> is between 1.8V and 5.5V. I<sup>2</sup>C operation is not guaranteed below 1.8V. Timekeeping operation is maintained with V<sub>CC</sub> as low as 1.3V.

### APPLICATIONS

Handhelds (GPS, POS Terminal, MP3 Player)  
 Consumer Electronics (Set-Top Box, VCR/Digital Recording)  
 Office Equipment (Fax/Printer, Copier)  
 Medical (Glucometer, Medicine Dispenser)  
 Telecommunications (Router, Switch, Server)  
 Other (Utility Meter, Vending Machine, Thermostat, Modem)

### TYPICAL OPERATING CIRCUIT



### FEATURES

- **Real-Time Clock (RTC) Counts Seconds, Minutes, Hours, Day, Date, Month, and Year with Leap-Year Compensation Valid Up to 2100**
- **Available in a Surface-Mount Package with an Integrated Crystal (DS1337C)**
- **I<sup>2</sup>C Serial Interface**
- **Two Time-of-Day Alarms**
- **Oscillator Stop Flag**
- **Programmable Square-Wave Output Defaults to 32kHz on Power-Up**
- **Available in 8-Pin DIP, SO, or  $\mu$ SOP**
- **-40°C to +85°C Operating Temperature Range**

### ORDERING INFORMATION

| PART     | TEMP RANGE     | PIN-PACKAGE      | TOP MARK† |
|----------|----------------|------------------|-----------|
| DS1337+  | -40°C to +85°C | 8 DIP (300 mils) | DS1337    |
| DS1337S+ | -40°C to +85°C | 8 SO (150 mils)  | DS1337    |
| DS1337U+ | -40°C to +85°C | 8 $\mu$ SOP      | 1337      |
| DS1337C# | -40°C to +85°C | 16 SO (300 mils) | DS1337C   |

+ Denotes a lead(Pb)-free/RoHS-compliant device.  
 # Denotes a RoHS-compliant device that may include lead that is exempt under the RoHS requirements. The lead finish is JESD97 category e3, and is compatible with both lead-based and lead-free soldering processes.  
 † A "+" anywhere on the top mark denotes a lead-free device. A "#" denotes a RoHS-compliant device.

**Pin Configurations appear at end of data sheet.**

**ABSOLUTE MAXIMUM RATINGS**

|  |                                       |
|--|---------------------------------------|
| Voltage Range on Any Pin Relative to Ground..... | -0.3V to +6.0V                        |
| Operating Temperature Range (Noncondensing)..... | -40°C to +85°C                        |
| Storage Temperature Range.....                   | -55°C to +125°C                       |
| Soldering Temperature.....                       | See IPC/JEDEC J-STD-020 Specification |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.

**RECOMMENDED DC OPERATING CONDITIONS**

(T<sub>A</sub> = -40°C to +85°C)

| PARAMETER                      | SYMBOL           | CONDITIONS   | MIN                   | TYP | MAX                    | UNITS |
|--------------------------------|------------------|--|-----------------------|-----|------------------------|-------|
| V <sub>CC</sub> Supply Voltage | V <sub>CC</sub>  | Full operation   | 1.8                   | 3.3 | 5.5                    | V     |
|                                | V <sub>CCT</sub> | Timekeeping (Note 5)                                     | 1.3                   |     | 1.8                    | V     |
| Logic 1                        | V <sub>IH</sub>  | SCL, SDA   | 0.7 x V <sub>CC</sub> |     | V <sub>CC</sub> + 0.3  | V     |
|                                |                  | $\overline{\text{INTA}}$ , SQW/ $\overline{\text{INTB}}$ |                       |     | 5.5                    |       |
| Logic 0                        | V <sub>IL</sub>  |  | -0.3                  |     | +0.3 x V <sub>CC</sub> | V     |

**DC ELECTRICAL CHARACTERISTICS—Full Operation**

(V<sub>CC</sub> = 1.8V to 5.5V, T<sub>A</sub> = -40°C to +85°C.) (Note 1)

| PARAMETER                               | SYMBOL           | CONDITIONS   | MIN | TYP | MAX | UNITS |
|---|------------------|--------------|-----|-----|-----|-------|
| Input Leakage                           | I <sub>LI</sub>  | (Note 2)     | -1  |     | +1  | μA    |
| I/O Leakage                             | I <sub>LO</sub>  | (Note 3)     | -1  |     | +1  | μA    |
| Logic 0 Output (V <sub>OL</sub> = 0.4V) | I <sub>OL</sub>  | (Note 3)     |     |     | 3   | mA    |
| Active Supply Current                   | I <sub>CCA</sub> | (Note 4)     |     |     | 150 | μA    |
| Standby Current                         | I <sub>CCS</sub> | (Notes 5, 6) |     |     | 1.5 | μA    |

**DC ELECTRICAL CHARACTERISTICS--Timekeeping**

(V<sub>CC</sub> = 1.3V to 1.8V, T<sub>A</sub> = -40°C to +85°C.) (Note 1)

| PARAMETER                                       | SYMBOL              | CONDITIONS         | MIN | TYP | MAX | UNITS |
|---|---------------------|--------------------|-----|-----|-----|-------|
| Timekeeping Current<br>(Oscillator Enabled)     | I <sub>CCTOSC</sub> | (Notes 5, 7, 8, 9) |     | 425 | 600 | nA    |
| Data-Retention Current<br>(Oscillator Disabled) | I <sub>CCTDDR</sub> | (Notes 5, 9)       |     |     | 100 | nA    |

**AC ELECTRICAL CHARACTERISTICS**(V<sub>CC</sub> = 1.8V to 5.5V, T<sub>A</sub> = -40°C to +85°C.) (Note 1)

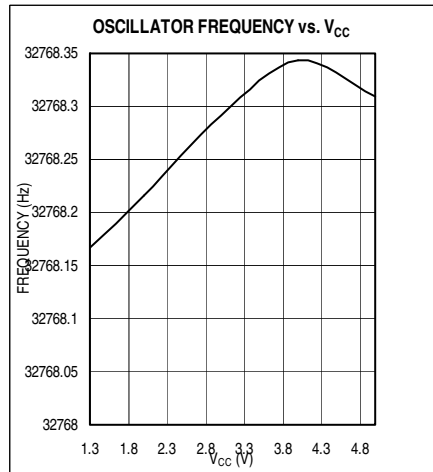
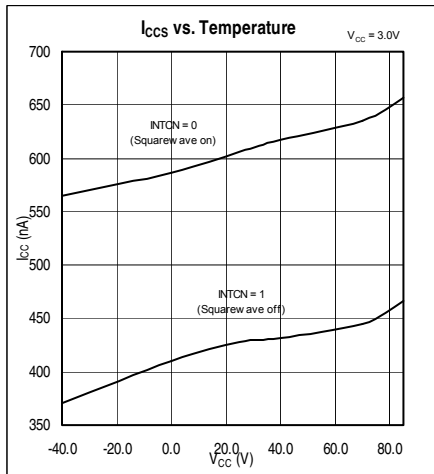
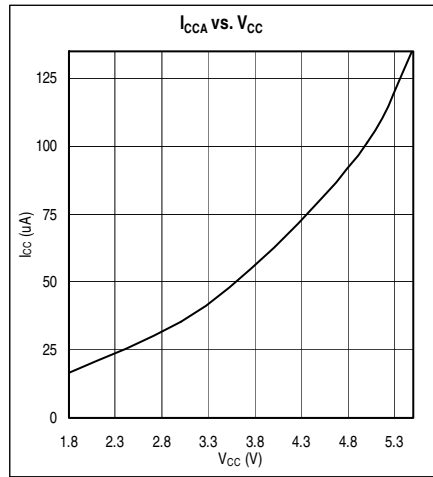
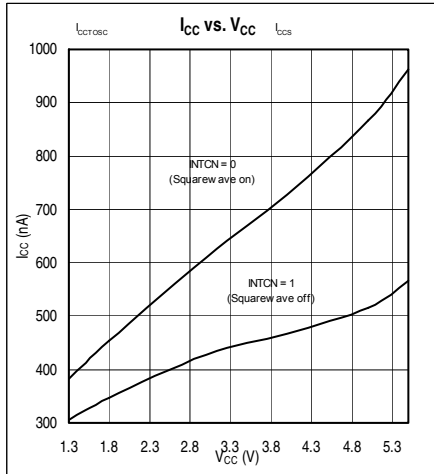
| PARAMETER  | SYMBOL              | CONDITIONS    | MIN                    | TYP | MAX  | UNITS |
|--|---------------------|---------------|------------------------|-----|------|-------|
| SCL Clock Frequency                              | f <sub>SCL</sub>    | Fast mode     | 100                    |     | 400  | kHz   |
|  |                     | Standard mode | 0                      |     | 100  |       |
| Bus Free Time Between a STOP and START Condition | t <sub>BUF</sub>    | Fast mode     | 1.3                    |     |      | μs    |
|  |                     | Standard mode | 4.7                    |     |      |       |
| Hold Time (Repeated) START Condition (Note 10)   | t <sub>HD:STA</sub> | Fast mode     | 0.6                    |     |      | μs    |
|  |                     | Standard mode | 4.0                    |     |      |       |
| LOW Period of SCL Clock                          | t <sub>LOW</sub>    | Fast mode     | 1.3                    |     |      | μs    |
|  |                     | Standard mode | 4.7                    |     |      |       |
| HIGH Period of SCL Clock                         | t <sub>HIGH</sub>   | Fast mode     | 0.6                    |     |      | μs    |
|  |                     | Standard mode | 4.0                    |     |      |       |
| Setup Time for a Repeated START Condition        | t <sub>SU:STA</sub> | Fast mode     | 0.6                    |     |      | μs    |
|  |                     | Standard mode | 4.7                    |     |      |       |
| Data Hold Time (Notes 11, 12)                    | t <sub>HD:DAT</sub> | Fast mode     | 0                      |     | 0.9  | μs    |
|  |                     | Standard mode | 0                      |     |      |       |
| Data Setup Time (Note 13)                        | t <sub>SU:DAT</sub> | Fast mode     | 100                    |     |      | ns    |
|  |                     | Standard mode | 250                    |     |      |       |
| Rise Time of Both SDA and SCL Signals (Note 14)  | t <sub>R</sub>      | Fast mode     | 20 + 0.1C <sub>B</sub> |     | 300  | ns    |
|  |                     | Standard mode | 20 + 0.1C <sub>B</sub> |     | 1000 |       |
| Fall Time of Both SDA and SCL Signals (Note 14)  | t <sub>F</sub>      | Fast mode     | 20 + 0.1C <sub>B</sub> |     | 300  | ns    |
|  |                     | Standard mode | 20 + 0.1C <sub>B</sub> |     | 300  |       |
| Setup Time for STOP Condition                    | t <sub>SU:STO</sub> | Fast mode     | 0.6                    |     |      | μs    |
|  |                     | Standard mode | 4.0                    |     |      |       |
| Capacitive Load for Each Bus Line                | C <sub>B</sub>      | (Note 14)     |                        |     | 400  | pF    |
| I/O Capacitance (SDA, SCL)                       | C <sub>I/O</sub>    | (Note 15)     |                        |     | 10   | pF    |
| Oscillator Stop Flag (OSF) Delay                 | t <sub>OSF</sub>    |               |                        | 100 |      | ms    |

**Note 1:** Limits at -40°C are guaranteed by design and are not production tested.**Note 2:** SCL only.**Note 3:** SDA,  $\overline{\text{INTA}}$ , and  $\overline{\text{SQW/INTB}}$ .**Note 4:** I<sub>CCA</sub>—SCL clocking at max frequency = 400kHz, V<sub>IL</sub> = 0.0V, V<sub>IH</sub> = V<sub>CC</sub>.**Note 5:** Specified with the I<sup>2</sup>C bus inactive, V<sub>IL</sub> = 0.0V, V<sub>IH</sub> = V<sub>CC</sub>.**Note 6:** SQW enabled.**Note 7:** Specified with the SQW function disabled by setting INTCN = 1.**Note 8:** Using recommended crystal on X1 and X2.**Note 9:** The device is fully accessible when 1.8 ≤ V<sub>CC</sub> ≤ 5.5V. Time and date are maintained when 1.3V ≤ V<sub>CC</sub> ≤ 1.8V.**Note 10:** After this period, the first clock pulse is generated**Note 11:** A device must internally provide a hold time of at least 300ns for the SDA signal (referred to the V<sub>IHMIN</sub> of the SCL signal) to bridge the undefined region of the falling edge of SCL.**Note 12:** The maximum t<sub>HD:DAT</sub> need only be met if the device does not stretch the LOW period (t<sub>LOW</sub>) of the SCL signal.**Note 13:** A fast-mode device can be used in a standard-mode system, but the requirement t<sub>SU:DAT</sub> ≥ to 250ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t<sub>Rmax</sub> + t<sub>SU:DAT</sub> = 1000 + 250 = 1250ns before the SCL line is released.**Note 14:** C<sub>B</sub>—total capacitance of one bus line in pF.**Note 15:** Guaranteed by design. Not production tested.

**Note 16:** The parameter  $t_{OSF}$  is the period of time that the oscillator must be stopped for the OSF bit to be set over the voltage range of  $V_{CC(MIN)} \leq V_{CC} \leq V_{CC(MAX)}$ .

## TYPICAL OPERATING CHARACTERISTICS

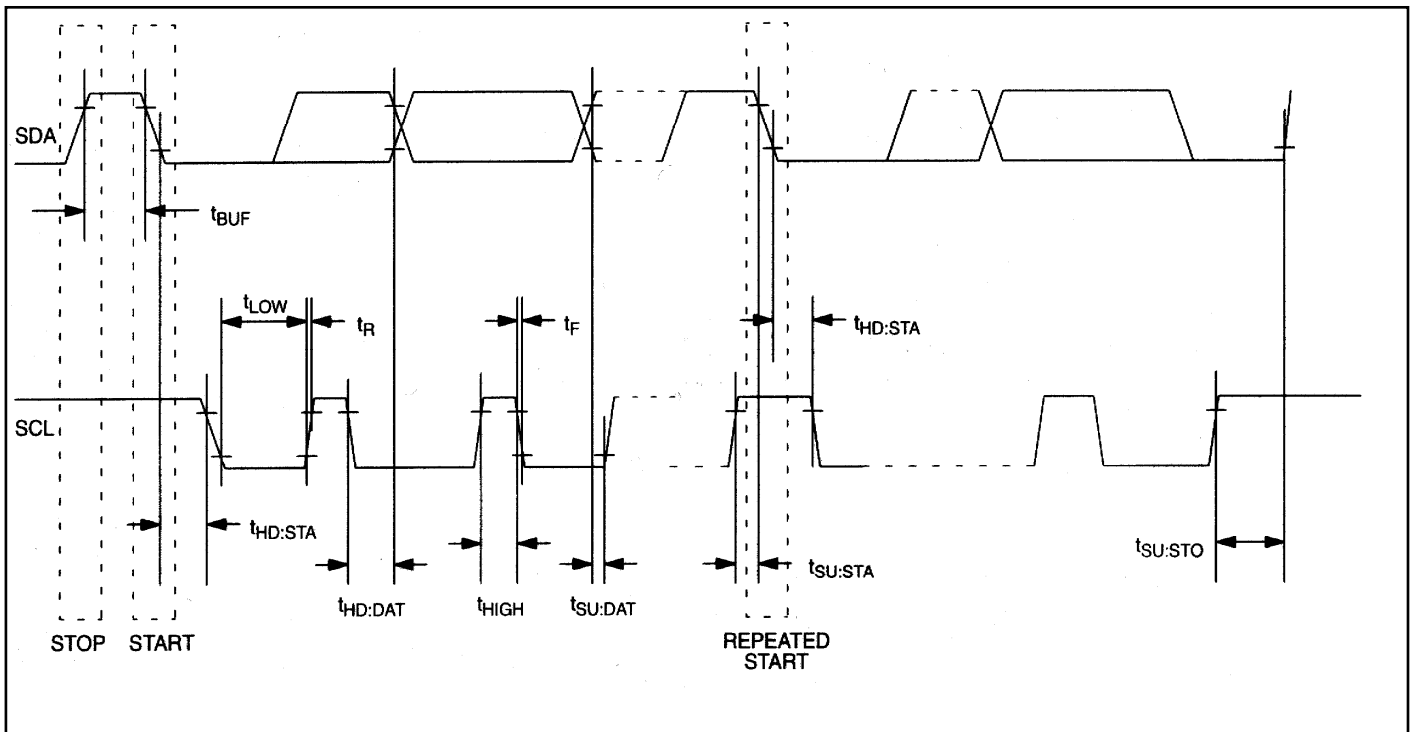
( $V_{CC} = 3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



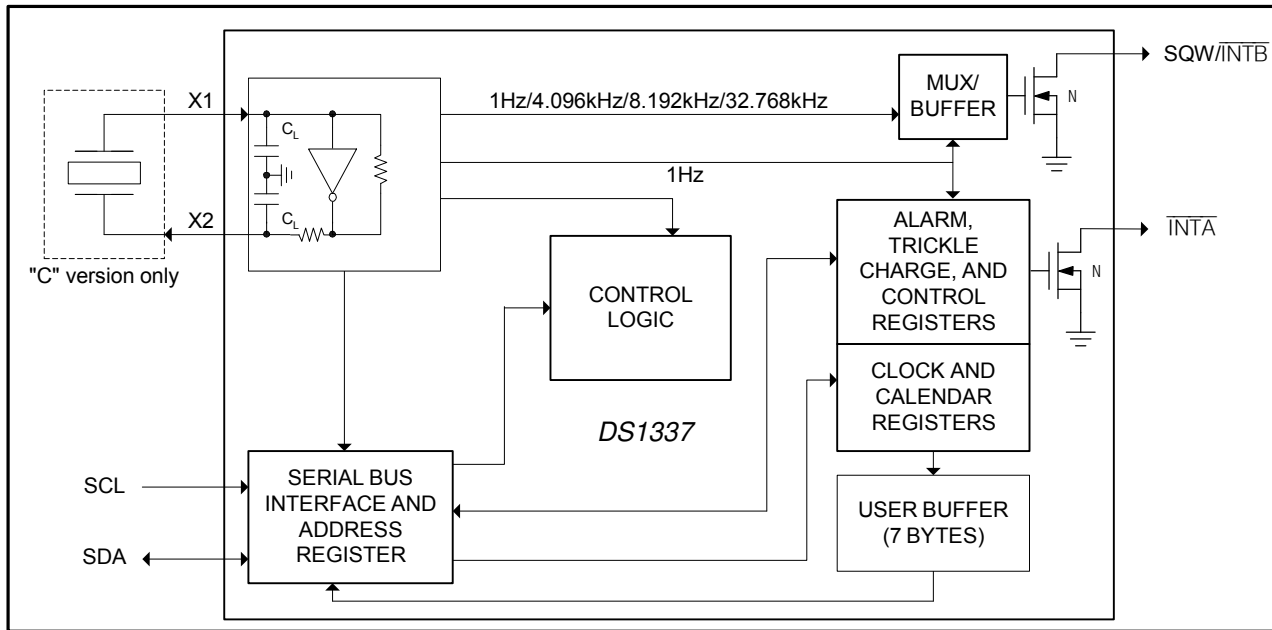
## PIN DESCRIPTION

| PIN |      | NAME                          | FUNCTION   |
|-----|------|-------------------------------|--|
| 8   | 16   |                               |  |
| 1   | —    | X1                            | Connections for a Standard 32.768kHz Quartz Crystal. The internal oscillator circuitry is designed for operation with a crystal having a specified load capacitance ( $C_L$ ) of 6pF. For more information about crystal selection and crystal layout considerations, refer to <i>Application Note 58: Crystal Considerations with Dallas Real-Time Clocks</i> . An external 32.768kHz oscillator can also drive the DS1337. In this configuration, the X1 pin is connected to the external oscillator signal and the X2 pin is floated. |
| 2   | —    | X2                            |  |
| 3   | 14   | $\overline{\text{INTA}}$      | Interrupt Output. When enabled, $\overline{\text{INTA}}$ is asserted low when the time/day/date matches the values set in the alarm registers. This pin is an open-drain output and requires an external pullup resistor. The pull up voltage may be up to 5.5V, regardless of the voltage on $V_{CC}$ . If not used, this pin may be left floating.   |
| 4   | 15   | GND                           | Ground. DC power is provided to the device on this pin.  |
| 5   | 16   | SDA                           | Serial Data Input/Output. SDA is the input/output pin for the I <sup>2</sup> C serial interface. The SDA pin is open-drain output and requires an external pullup resistor.  |
| 6   | 1    | SCL                           | Serial Clock Input. SCL is used to synchronize data movement on the serial interface.  |
| 7   | 2    | SQW/ $\overline{\text{INTB}}$ | Square-Wave/Interrupt Output. Programmable square-wave or interrupt output signal. It is an open-drain output and requires an external pullup resistor. The pull up voltage may be up to 5.5V, regardless of the voltage on $V_{CC}$ . If not used, this pin may be left floating.   |
| 8   | 3    | $V_{CC}$                      | DC Power. DC power is provided to the device on this pin.  |
| —   | 4–13 | N.C.                          | No Connect. These pins are not connected internally, but must be grounded for proper operation.  |

## TIMING DIAGRAM



## BLOCK DIAGRAM



## DETAILED DESCRIPTION

The *Block Diagram* shows the main elements of the DS1337. As shown, communications to and from the DS1337 occur serially over an I<sup>2</sup>C bus. The DS1337 operates as a slave device on the serial bus. Access is obtained by implementing a START condition and providing a device identification code, followed by data. Subsequent registers can be accessed sequentially until a STOP condition is executed. The device is fully accessible through the I<sup>2</sup>C interface whenever  $V_{CC}$  is between 5.5V and 1.8V. I<sup>2</sup>C operation is not guaranteed when  $V_{CC}$  is below 1.8V. The DS1337 maintains the time and date when  $V_{CC}$  is as low as 1.3V.

## OSCILLATOR CIRCUIT

The DS1337 uses an external 32.768kHz crystal. The oscillator circuit does not require any external resistors or capacitors to operate. [Table 1](#) specifies several crystal parameters for the external crystal. The *Block Diagram* shows a functional schematic of the oscillator circuit. The startup time is usually less than 1 second when using a crystal with the specified characteristics.

**Table 1. Crystal Specifications\***

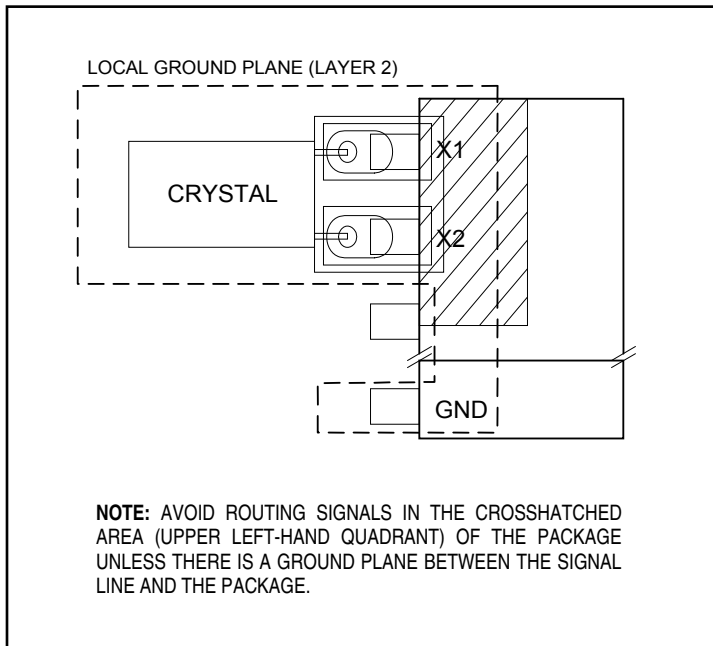
| PARAMETER         | SYMBOL | MIN | TYP    | MAX | UNITS      |
|-------------------|--------|-----|--------|-----|------------|
| Nominal Frequency | $f_o$  |     | 32.768 |     | kHz        |
| Series Resistance | ESR    |     |        | 50  | k $\Omega$ |
| Load Capacitance  | $C_L$  |     | 6      |     | pF         |

\*The crystal, traces, and crystal input pins should be isolated from RF generating signals. Refer to Application Note 58: Crystal Considerations for Dallas Real-Time Clocks for additional specifications.

## CLOCK ACCURACY

The accuracy of the clock is dependent upon the accuracy of the crystal and the accuracy of the match between the capacitive load of the oscillator circuit and the capacitive load for which the crystal was trimmed. Crystal frequency drift caused by temperature shifts creates additional error. External circuit noise coupled into the oscillator circuit can result in the clock running fast. [Figure 1](#) shows a typical PC board layout for isolating the crystal and oscillator from noise. Refer to *Application Note 58: Crystal Considerations with Dallas Real-Time Clocks* for detailed information.

**Figure 1. Typical PC Board Layout for Crystal**



### DS1337C ONLY

The DS1337C integrates a standard 32,768Hz crystal in the package. Typical accuracy at nominal  $V_{CC}$  and +25°C is approximately +10ppm. Refer to *Application Note 58* for information about crystal accuracy vs. temperature.

## OPERATING MODES

The amount of current consumed by the DS1337 is determined, in part, by the I<sup>2</sup>C interface and oscillator operation. The following table shows the relationship between the operating mode and the corresponding  $I_{CC}$  parameter.

| Operating Mode   | $V_{CC}$                     | Power                              |
|--|------------------------------|------------------------------------|
| I <sup>2</sup> C Interface Active                          | $1.8V \leq V_{CC} \leq 5.5V$ | $I_{CC}$ Active ( $I_{CCA}$ )      |
| I <sup>2</sup> C Interface Inactive                        | $1.8V \leq V_{CC} \leq 5.5V$ | $I_{CC}$ Standby ( $I_{CCS}$ )     |
| I <sup>2</sup> C Interface Inactive                        | $1.3V \leq V_{CC} \leq 1.8V$ | Timekeeping ( $I_{CCTOSC}$ )       |
| I <sup>2</sup> C Interface Inactive<br>Oscillator Disabled | $1.3V \leq V_{CC} \leq 1.8V$ | Data Retention<br>( $I_{CCTDDR}$ ) |



## ADDRESS MAP

[Table 2](#) shows the address map for the DS1337 registers. During a multibyte access, when the address pointer reaches the end of the register space (0Fh) it wraps around to location 00h. On an I<sup>2</sup>C START, STOP, or address pointer incrementing to location 00h, the current time is transferred to a second set of registers. The time information is read from these secondary registers, while the clock may continue to run. This eliminates the need to re-read the registers in case of an update of the main registers during a read.

**Table 2. Timekeeper Registers**

| ADDRESS | BIT 7   | BIT 6      | BIT 5   | BIT 4    | BIT 3   | BIT 2 | BIT 1 | BIT 0             | FUNCTION           | RANGE                    |
|---------|---------|------------|---------|----------|---------|-------|-------|-------------------|--------------------|--------------------------|
| 00H     | 0       | 10 Seconds |         |          | Seconds |       |       |                   | Seconds            | 00–59                    |
| 01H     | 0       | 10 Minutes |         |          | Minutes |       |       |                   | Minutes            | 00–59                    |
| 02H     | 0       | 12/24      | AM/PM   | 10 Hour  | Hour    |       |       |                   | Hours              | 1–12<br>+AM/PM<br>00–23  |
|         |         |            | 10 Hour |          |         |       |       |                   |                    |                          |
| 03H     | 0       | 0          | 0       | 0        | 0       | Day   |       |                   | Day                | 1–7                      |
| 04H     | 0       | 0          | 10 Date |          | Date    |       |       | Date              | Date               | 01–31                    |
| 05H     | Century | 0          | 0       | 10 Month | Month   |       |       | Month/<br>Century | Month/<br>Century  | 01–12 +<br>Century       |
| 06H     | 10 Year |            |         |          | Year    |       |       | Year              | Year               | 00–99                    |
| 07H     | A1M1    | 10 Seconds |         |          | Seconds |       |       |                   | Alarm 1<br>Seconds | 00–59                    |
| 08H     | A1M2    | 10 Minutes |         |          | Minutes |       |       |                   | Alarm 1<br>Minutes | 00–59                    |
| 09H     | A1M3    | 12/24      | AM/PM   | 10 Hour  | Hour    |       |       |                   | Alarm 1<br>Hours   | 1–12 +<br>AM/PM<br>00–23 |
|         |         |            | 10 Hour |          |         |       |       |                   |                    |                          |
| 0AH     | A1M4    | DY/DT      | 10 Date |          | Day     |       |       | Alarm 1<br>Day    | Alarm 1<br>Date    | 1–7<br>01–31             |
|         |         |            |         |          |         |       |       |                   |                    |                          |
| 0BH     | A2M2    | 10 Minutes |         |          | Minutes |       |       |                   | Alarm 2<br>Minutes | 00–59                    |
| 0CH     | A2M3    | 12/24      | AM/PM   | 10 Hour  | Hour    |       |       |                   | Alarm 2<br>Hours   | 1–12 +<br>AM/PM<br>00–23 |
|         |         |            | 10 Hour |          |         |       |       |                   |                    |                          |
| 0DH     | A2M4    | DY/DT      | 10 Date |          | Day     |       |       | Alarm 2<br>Day    | Alarm 2<br>Date    | 1–7<br>01–31             |
|         |         |            |         |          |         |       |       |                   |                    |                          |
| 0EH     | EOSC    | 0          | 0       | RS2      | RS1     | INTCN | A2IE  | A1IE              | Control            | —                        |
| 0FH     | OSF     | 0          | 0       | 0        | 0       | 0     | A2F   | A1F               | Status             | —                        |

**Note:** Unless otherwise specified, the state of the registers is not defined when power is first applied or  $V_{CC}$  falls below the  $V_{OSC}$ .

## I<sup>2</sup>C INTERFACE

The I<sup>2</sup>C interface is accessible whenever  $V_{CC}$  is at a valid level. If a microcontroller connected to the DS1337 resets while reading from the DS1337 during an I<sup>2</sup>C read, the two could become unsynchronized. The microcontroller must terminate the last byte read with a Not-Acknowledge (NACK) to properly terminate the read. When the microcontroller resets, the DS1337 I<sup>2</sup>C interface may be placed into a known state by toggling SCL until SDA is observed to be at a high level. At that point the microcontroller should pull SDA low while SCL is high, generating a START condition.

## CLOCK AND CALENDAR

The time and calendar information is obtained by reading the appropriate register bytes. The RTC registers are illustrated in [Table 2](#). The time and calendar are set or initialized by writing the appropriate register bytes. The contents of the time and calendar registers are in the binary-coded decimal (BCD) format.

The day-of-week register increments at midnight. Values that correspond to the day of week are user-defined but must be sequential (i.e., if 1 equals Sunday, then 2 equals Monday, and so on.). Illogical time and date entries result in undefined operation.

When reading or writing the time and date registers, secondary (user) buffers are used to prevent errors when the internal registers update. When reading the time and date registers, the user buffers are synchronized to the internal registers on any start or stop and when the register pointer rolls over to zero.

The countdown chain is reset whenever the seconds register is written. Write transfers occur on the acknowledge pulse from the device. To avoid rollover issues, once the countdown chain is reset, the remaining time and date registers must be written within 1 second. The 1Hz square-wave output, if enable, transitions high 500ms after the seconds data transfer, provided the oscillator is already running.

The DS1337 can be run in either 12-hour or 24-hour mode. Bit 6 of the hours register is defined as the 12- or 24-hour mode-select bit. When high, the 12-hour mode is selected. In the 12-hour mode, bit 5 is the  $\overline{\text{AM/PM}}$  bit with logic high being PM. In the 24-hour mode, bit 5 is the second 10-hour bit (20–23 hours). All hours values, including the alarms, must be reinitialized whenever the 12/24-hour mode bit is changed. The century bit (bit 7 of the month register) is toggled when the years register overflows from 99–00.

## ALARMS

The DS1337 contains two time-of-day/date alarms. Alarm 1 can be set by writing to registers 07h–0Ah. Alarm 2 can be set by writing to registers 0Bh–0Dh. The alarms can be programmed (by the INTCN bit of the control register) to operate in two different modes—each alarm can drive its own separate interrupt output or both alarms can drive a common interrupt output. Bit 7 of each of the time-of-day/date alarm registers are mask bits ([Table 2](#)). When all of the mask bits for each alarm are logic 0, an alarm only occurs when the values in the timekeeping registers 00h–06h match the values stored in the time-of-day/date alarm registers. The alarms can also be programmed to repeat every second, minute, hour, day, or date. [Table 3](#) shows the possible settings. Configurations not listed in the table result in illogical operation.

The  $\overline{\text{DY/DT}}$  bits (bit 6 of the alarm day/date registers) control whether the alarm value stored in bits 0–5 of that register reflects the day of the week or the date of the month. If  $\overline{\text{DY/DT}}$  is written to logic 0, the alarm is the result of a match with date of the month. If  $\overline{\text{DY/DT}}$  is written to logic 1, the alarm is the result of a match with day of the week.

When the RTC register values match alarm register settings, the corresponding alarm flag (A1F or A2F) bit is set to logic 1. The bit(s) will remain at a logic 1 until written to a logic 0 by the user. If the corresponding alarm interrupt enable (A1IE or A2IE) is also set to logic 1, the alarm condition activates one of the interrupt output ( $\overline{\text{INTA}}$  or  $\overline{\text{SQW/INTB}}$ ) signals. The match is tested on the once-per-second update of the time and date registers.

**Table 3. Alarm Mask Bits**

| DY/ $\overline{DT}$ | ALARM 1 REGISTER MASK BITS<br>(BIT 7) |      |      |      | ALARM RATE   |
|---------------------|---------------------------------------|------|------|------|--|
|                     | A1M4                                  | A1M3 | A1M2 | A1M1 |  |
| X                   | 1                                     | 1    | 1    | 1    | Alarm once per second                              |
| X                   | 1                                     | 1    | 1    | 0    | Alarm when seconds match                           |
| X                   | 1                                     | 1    | 0    | 0    | Alarm when minutes and seconds match               |
| X                   | 1                                     | 0    | 0    | 0    | Alarm when hours, minutes, and seconds match       |
| 0                   | 0                                     | 0    | 0    | 0    | Alarm when date, hours, minutes, and seconds match |
| 1                   | 0                                     | 0    | 0    | 0    | Alarm when day, hours, minutes, and seconds match  |

| DY/ $\overline{DT}$ | ALARM 2 REGISTER MASK BITS<br>(BIT 7) |      |      | ALARM RATE   |
|---------------------|---------------------------------------|------|------|--|
|                     | A2M4                                  | A2M3 | A2M2 |  |
| X                   | 1                                     | 1    | 1    | Alarm once per minute (00 seconds of every minute) |
| X                   | 1                                     | 1    | 0    | Alarm when minutes match                           |
| X                   | 1                                     | 0    | 0    | Alarm when hours and minutes match                 |
| 0                   | 0                                     | 0    | 0    | Alarm when date, hours, and minutes match          |
| 1                   | 0                                     | 0    | 0    | Alarm when day, hours, and minutes match           |

## SPECIAL-PURPOSE REGISTERS

The DS1337 has two additional registers (control and status) that control the RTC, alarms, and square-wave output.

### Control Register (0Eh)

| Bit 7             | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------------------|-------|-------|-------|-------|-------|-------|-------|
| $\overline{EOSC}$ | 0     | 0     | RS2   | RS1   | INTCN | A2IE  | A1IE  |

**Bit 7: Enable Oscillator ( $\overline{EOSC}$ ).** This active-low bit when set to logic 0 starts the oscillator. When this bit is set to logic 1, the oscillator is stopped. This bit is enabled (logic 0) when power is first applied.

**Bits 4 and 3: Rate Select (RS2 and RS1).** These bits control the frequency of the square-wave output when the square wave has been enabled. The table below shows the square-wave frequencies that can be selected with the RS bits. These bits are both set to logic 1 (32kHz) when power is first applied.

### SQW/ $\overline{INTB}$ Output

| INTCN | RS2 | RS1 | SQW/ $\overline{INTB}$<br>OUTPUT | A2IE |
|-------|-----|-----|----------------------------------|------|
| 0     | 0   | 0   | 1Hz                              | X    |
| 0     | 0   | 1   | 4.096kHz                         | X    |
| 0     | 1   | 0   | 8.192kHz                         | X    |
| 0     | 1   | 1   | 32.768kHz                        | X    |
| 1     | X   | X   | $\overline{A2F}$                 | 1    |

**Bit 2: Interrupt Control (INTCN).** This bit controls the relationship between the two alarms and the interrupt output pins. When the  $\overline{INTCN}$  bit is set to logic 1, a match between the timekeeping registers and the alarm 1 registers activates the  $\overline{INTA}$  pin (provided that the alarm is enabled) and a match between the timekeeping registers and the alarm 2 registers activates the SQW/ $\overline{INTB}$  pin (provided that the alarm is enabled). When the  $\overline{INTCN}$  bit is set to logic 0, a square wave is output on the SQW/ $\overline{INTB}$  pin. This bit is set to logic 0 when power is first applied.

**Bit 1: Alarm 2 Interrupt Enable (A2IE).** When set to logic 1, this bit permits the alarm 2 flag (A2F) bit in the status register to assert  $\overline{\text{INTA}}$  (when  $\text{INTCN} = 0$ ) or to assert  $\text{SQW}/\overline{\text{INTB}}$  (when  $\text{INTCN} = 1$ ). When the A2IE bit is set to logic 0, the A2F bit does not initiate an interrupt signal. The A2IE bit is disabled (logic 0) when power is first applied.

**Bit 0: Alarm 1 Interrupt Enable (A1IE).** When set to logic 1, this bit permits the alarm 1 flag (A1F) bit in the status register to assert  $\overline{\text{INTA}}$ . When the A1IE bit is set to logic 0, the A1F bit does not initiate the  $\overline{\text{INTA}}$  signal. The A1IE bit is disabled (logic 0) when power is first applied.

### Status Register (0Fh)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| OSF   | 0     | 0     | 0     | 0     | 0     | A2F   | A1F   |

**Bit 7: Oscillator Stop Flag (OSF).** A logic 1 in this bit indicates that the oscillator either is stopped or was stopped for some period of time and may be used to judge the validity of the clock and calendar data. This bit is set to logic 1 anytime that the oscillator stops. The following are examples of conditions that can cause the OSF bit to be set:

- 1) The first time power is applied.
- 2) The voltage present on  $V_{CC}$  is insufficient to support oscillation.
- 3) The  $\overline{\text{EOSC}}$  bit is turned off.
- 4) External influences on the crystal (e.g., noise, leakage, etc.).

This bit remains at logic 1 until written to logic 0.

**Bit 1: Alarm 2 Flag (A2F).** A logic 1 in the alarm 2 flag bit indicates that the time matched the alarm 2 registers. This flag can be used to generate an interrupt on either  $\overline{\text{INTA}}$  or  $\text{SQW}/\overline{\text{INTB}}$  depending on the status of the  $\text{INTCN}$  bit in the control register. If the  $\text{INTCN}$  bit is set to logic 0 and A2F is at logic 1 (and A2IE bit is also logic 1), the  $\overline{\text{INTA}}$  pin goes low. If the  $\text{INTCN}$  bit is set to logic 1 and A2F is logic 1 (and A2IE bit is also logic 1), the  $\text{SQW}/\overline{\text{INTB}}$  pin goes low. A2F is cleared when written to logic 0. This bit can only be written to logic 0. Attempting to write to logic 1 leaves the value unchanged.

**Bit 0: Alarm 1 Flag (A1F).** A logic 1 in the alarm 1 flag bit indicates that the time matched the alarm 1 registers. If the A1IE bit is also logic 1, the  $\overline{\text{INTA}}$  pin goes low. A1F is cleared when written to logic 0. This bit can only be written to logic 0. Attempting to write to logic 1 leaves the value unchanged.

## I<sup>2</sup>C SERIAL DATA BUS

The DS1337 supports the I<sup>2</sup>C bus protocol. A device that sends data onto the bus is defined as a transmitter and a device receiving data as a receiver. The device that controls the message is called a master. The devices that are controlled by the master are referred to as slaves. A master device that generates the serial clock (SCL), controls the bus access, and generates the START and STOP conditions must control the bus. The DS1337 operates as a slave on the I<sup>2</sup>C bus. Within the bus specifications a standard mode (100kHz maximum clock rate) and a fast mode (400kHz maximum clock rate) are defined. The DS1337 works in both modes. Connections to the bus are made through the open-drain I/O lines SDA and SCL.

The following bus protocol has been defined ([Figure 2](#)):

- Data transfer may be initiated only when the bus is not busy.
- During data transfer, the data line must remain stable whenever the clock line is HIGH. Changes in the data line while the clock line is HIGH are interpreted as control signals.

Accordingly, the following bus conditions have been defined:

**Bus not busy:** Both data and clock lines remain HIGH.

**Start data transfer:** A change in the state of the data line, from HIGH to LOW, while the clock is HIGH, defines a START condition.

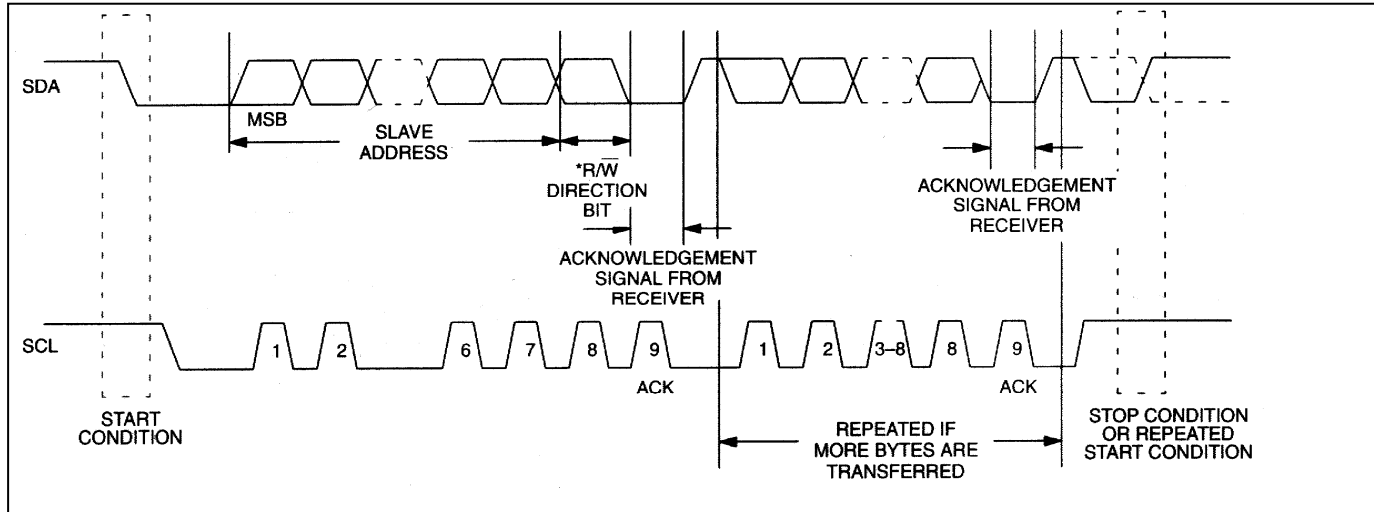
**Stop data transfer:** A change in the state of the data line, from LOW to HIGH, while the clock line is HIGH, defines the STOP condition.

**Data valid:** The state of the data line represents valid data when, after a START condition, the data line is stable for the duration of the HIGH period of the clock signal. The data on the line must be changed during the LOW period of the clock signal. There is one clock pulse per bit of data.

Each data transfer is initiated with a START condition and terminated with a STOP condition. The number of data bytes transferred between START and STOP conditions are not limited, and are determined by the master device. The information is transferred byte-wise and each receiver acknowledges with a ninth bit.

**Acknowledge:** Each receiving device, when addressed, is obliged to generate an acknowledge after the reception of each byte. The master device must generate an extra clock pulse that is associated with this acknowledge bit.

A device that acknowledges must pull down the SDA line during the acknowledge clock pulse in such a way that the SDA line is stable LOW during the HIGH period of the acknowledge-related clock pulse. Of course, setup and hold times must be taken into account. A master must signal an end of data to the slave by not generating an acknowledge bit on the last byte that has been clocked out of the slave. In this case, the slave must leave the data line HIGH to enable the master to generate the STOP condition.

**Figure 2. Data Transfer on I<sup>2</sup>C Serial Bus**

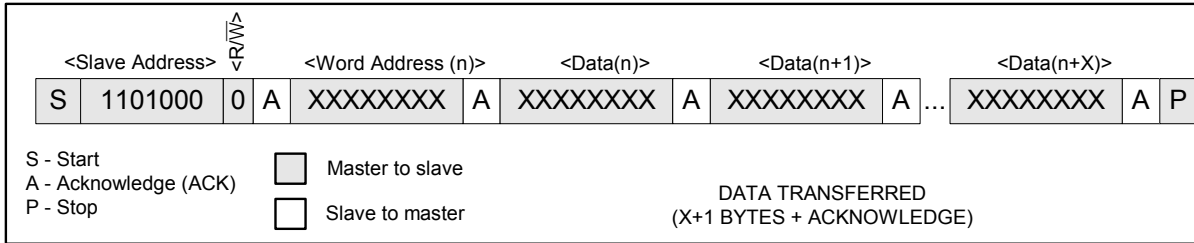
Depending upon the state of the  $R\bar{W}$  bit, two types of data transfer are possible:

- 1) **Data transfer from a master transmitter to a slave receiver.** The first byte transmitted by the master is the slave address. Next follows a number of data bytes. The slave returns an acknowledge bit after each received byte. Data is transferred with the most significant bit (MSB) first.
- 2) **Data transfer from a slave transmitter to a master receiver.** The master transmits the first byte (the slave address). The slave then returns an acknowledge bit, followed by the slave transmitting a number of data bytes. The master returns an acknowledge bit after all received bytes other than the last byte. At the end of the last received byte, a “not acknowledge” is returned. The master device generates all of the serial clock pulses and the START and STOP conditions. A transfer is ended with a STOP condition or with a repeated START condition. Since a repeated START condition is also the beginning of the next serial transfer, the bus is not released. Data is transferred with the most significant bit (MSB) first.

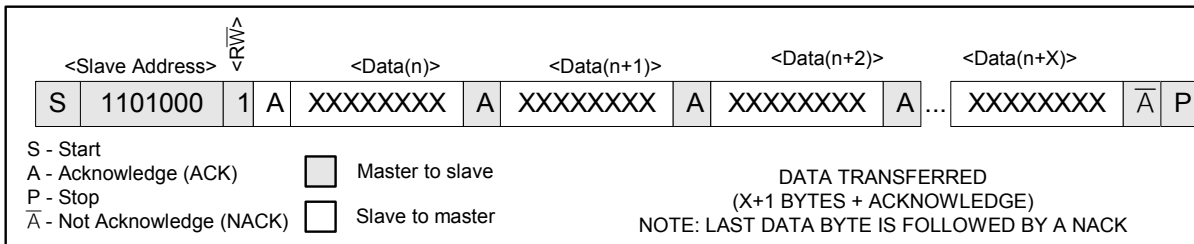
The DS1337 can operate in the following two modes:

- 1) **Slave Receiver Mode (Write Mode):** Serial data and clock are received through SDA and SCL. After each byte is received an acknowledge bit is transmitted. START and STOP conditions are recognized as the beginning and end of a serial transfer. Address recognition is performed by hardware after reception of the slave address and direction bit (Figure 3). The slave address byte is the first byte received after the master generates the START condition. The slave address byte contains the 7-bit DS1337 address, which is 1101000, followed by the direction bit ( $R\bar{W}$ ), which, for a write, is 0. After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. After the DS1337 acknowledges the slave address + write bit, the master transmits a register address to the DS1337. This sets the register pointer on the DS1337. The master may then transmit zero or more bytes of data, with the DS1337 acknowledging each byte received. The address pointer will increment after each data byte is transferred. The master generates a STOP condition to terminate the data write.
- 2) **Slave Transmitter Mode (Read Mode):** The first byte is received and handled as in the slave receiver mode. However, in this mode, the direction bit indicates that the transfer direction is reversed. Serial data is transmitted on SDA by the DS1337 while the serial clock is input on SCL. START and STOP conditions are recognized as the beginning and end of a serial transfer (Figure 4 and Figure 5). The slave address byte is the first byte received after the master generates a START condition. The slave address byte contains the 7-bit DS1337 address, which is 1101000, followed by the direction bit ( $R\bar{W}$ ), which, for a read, is 1. After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. The DS1337 then begins to transmit data starting with the register address pointed to by the register pointer. If the register pointer is not written to before the initiation of a read mode the first address that is read is the last one stored in the register pointer. The DS1337 must receive a “not acknowledge” to end a read.

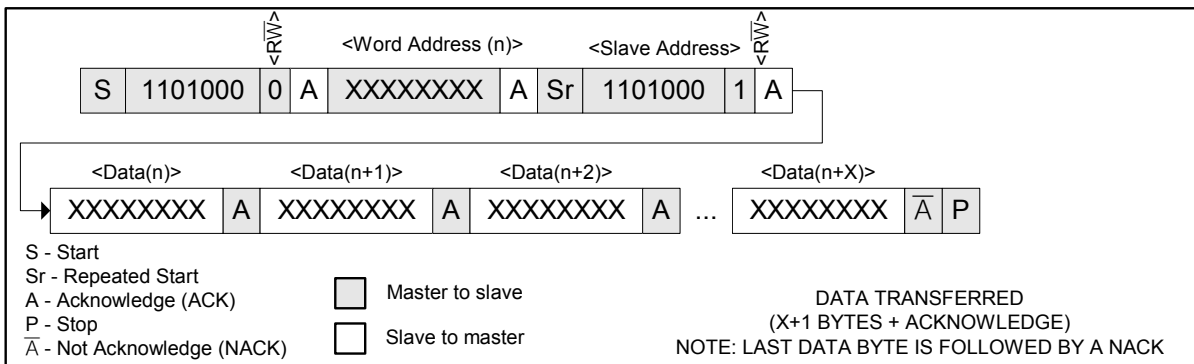
**Figure 3. Data Write—Slave Receiver Mode**



**Figure 4. Data Read (from Current Pointer Location)—Slave Transmitter Mode**



**Figure 5. Data Read (Write Pointer, Then Read)—Slave Receive and Transmit**



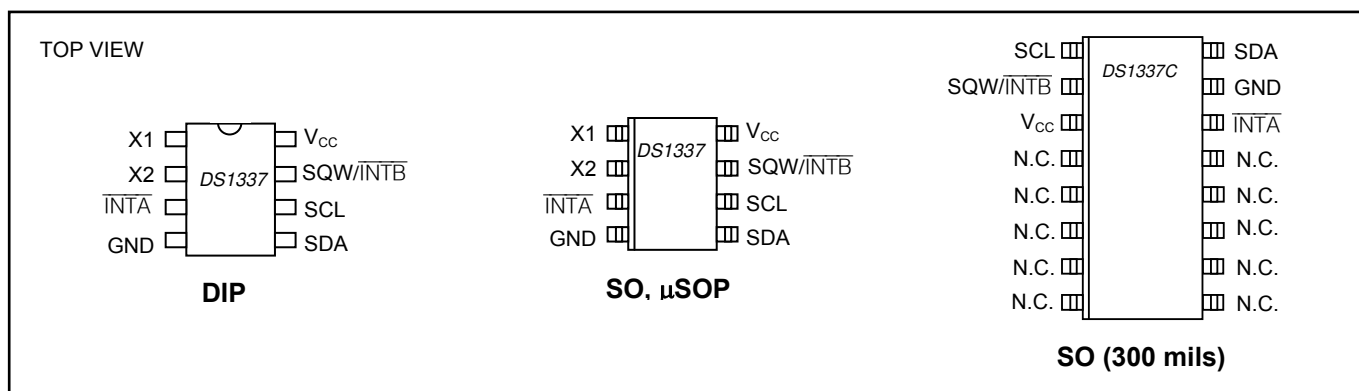
## HANDLING, PC BOARD LAYOUT, AND ASSEMBLY

The DS1337C package contains a quartz tuning-fork crystal. Pick-and-place equipment may be used, but precautions should be taken to ensure that excessive shocks are avoided. Ultrasonic cleaning should be avoided to prevent damage to the crystal.

Avoid running signal traces under the package, unless a ground plane is placed between the package and the signal line. All N.C. (no connect) pins must be connected to ground.

Moisture-sensitive packages are shipped from the factory dry-packed. Handling instructions listed on the package label must be followed to prevent damage during reflow. Refer to the IPC/JEDEC J-STD-020 standard for moisture-sensitive device (MSD) classifications.

## PIN CONFIGURATIONS



## CHIP INFORMATION

TRANSISTOR COUNT: 10,950

PROCESS: CMOS

## THERMAL INFORMATION

| PACKAGE     | THETA-J <sub>A</sub><br>(°C/W) | THETA-J <sub>C</sub><br>(°C/W) |
|-------------|--------------------------------|--------------------------------|
| 8 DIP       | 110                            | 40                             |
| 8 SO        | 170                            | 40                             |
| 8 $\mu$ SOP | 229                            | 39                             |
| 16 SO       | 73                             | 23                             |

## PACKAGE INFORMATION

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO.            |
|--------------|--------------|-------------------------|
| 8 PDIP       | P8+8         | <a href="#">21-0043</a> |
| 8 SO         | S8+2         | <a href="#">21-0041</a> |
| 8 $\mu$ MAX  | U8+1         | <a href="#">21-0036</a> |
| 16 SO        | W16-H2       | <a href="#">21-0042</a> |



## REVISION HISTORY

| REVISION DATE | DESCRIPTION   | PAGES CHANGED |
|---------------|---|---------------|
| 080508        | Added device access details to <i>General Description</i> section.  | 1             |
|               | Removed leaded ordering numbers from the <i>Ordering Information</i> table.                                     | 1             |
|               | Added Note 5 to Timekeeping V <sub>CC</sub> EC table range.   | 2             |
|               | Added "Full Operation" and "Timekeeping" to headers to clarify table usage.                                     | 2             |
|               | Added OSF parameter to EC table.  | 3             |
|               | Updated <i>Pin Description</i> to indicate max input voltage and that unused outputs may be left open.          | 5             |
|               | Added oscillator circuit and show open-drain transistors on <i>Block Diagram</i> .                              | 6             |
|               | Added <i>Operating Mode</i> section with details on operating mode and corresponding I <sub>CC</sub> parameter. | 7             |
|               | Added <i>I<sup>2</sup>C Interface</i> section explaining how to synchronize a microcontroller and the RTC.      | 8             |
|               | Corrected legend in figure 5 for not-acknowledge (add overbar to symbol).                                       | 14            |
| 071609        | Removed conflicting SDA/SCL input bias statement in <i>Pin Description</i> .                                    | 5             |



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